The Expanding Photosphere Method -- progress and problems

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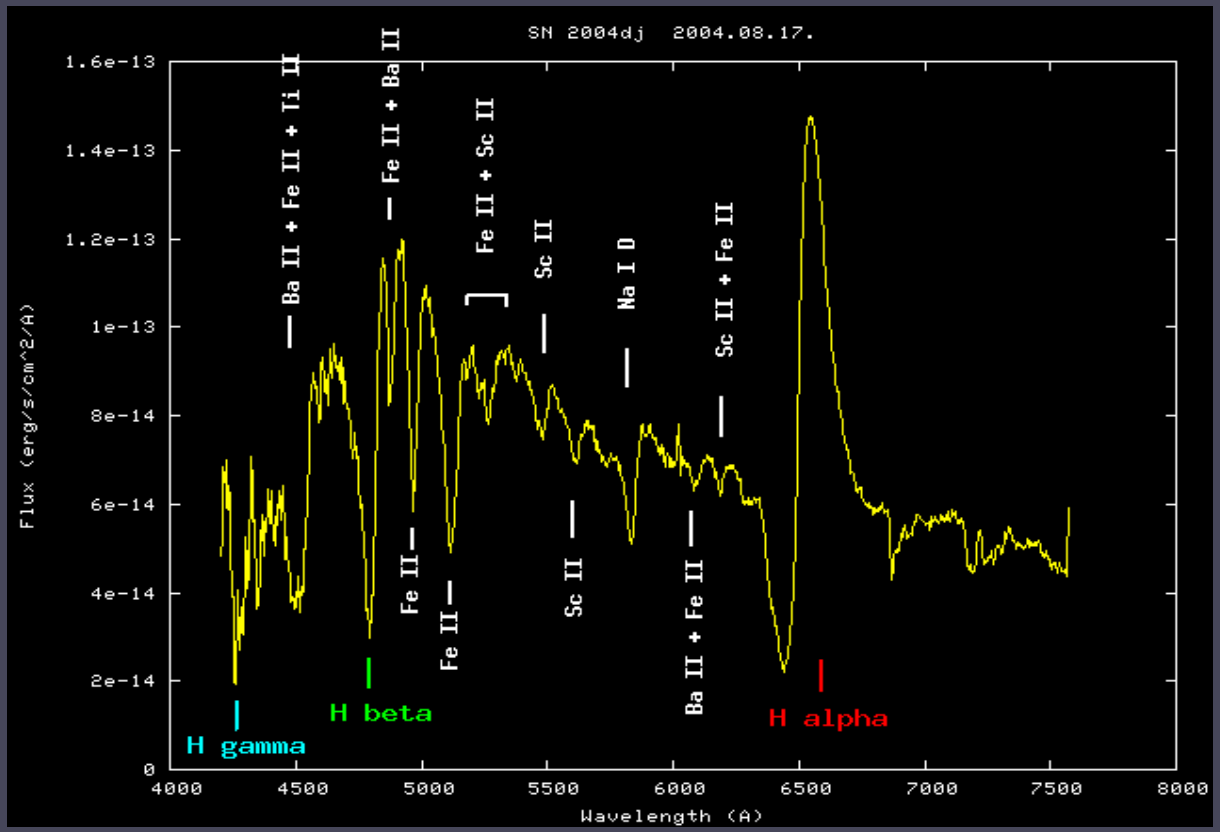
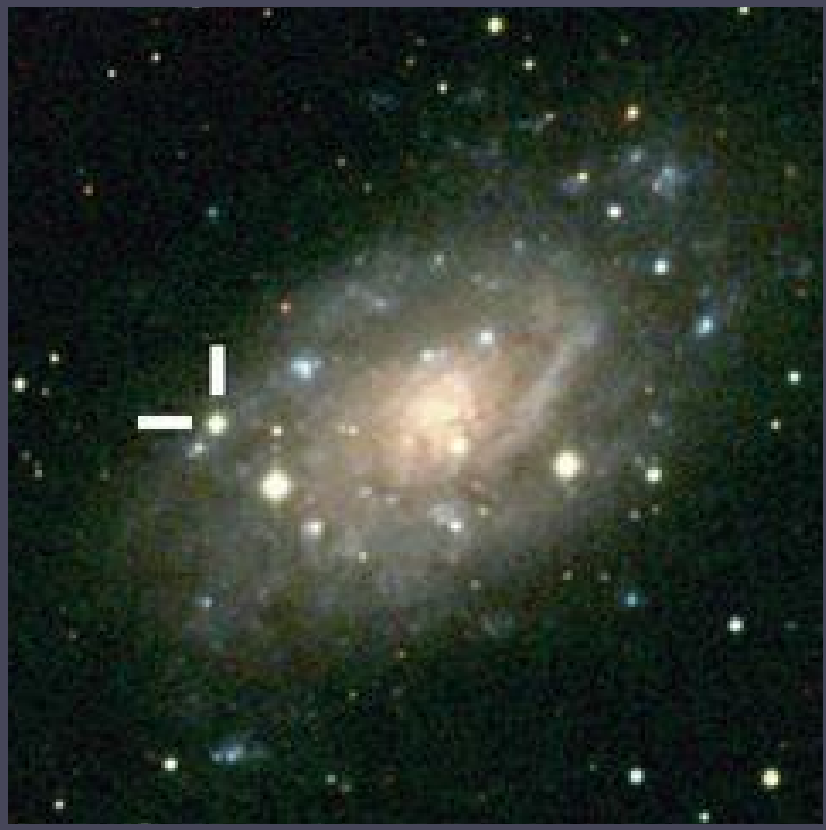




What is EPM?

- a distance measurement method

- „an art instead of an objective measurement tool”
  (M. Hamuy, 2001)

- „the whole concept appears suspect”
  (E. Baron et al., 2004)

Basic concepts (Kirshner & Kwan 1974)

- the ejecta is spherically symmetric
- the expansion is homologous
- a photosphere exists at $\tau = 2/3$

$$R_{phot} = R_0 + v_{phot}(t)\cdot\Delta t \approx v_{phot}\cdot\Delta t$$

- the photosphere radiates as a diluted blackbody

$$f_\lambda = \left(\frac{R_{phot}}{D}\right)^2 \zeta^2 \pi B_\lambda(T) = \Theta^2 \zeta^2 \pi B_\lambda(T)$$

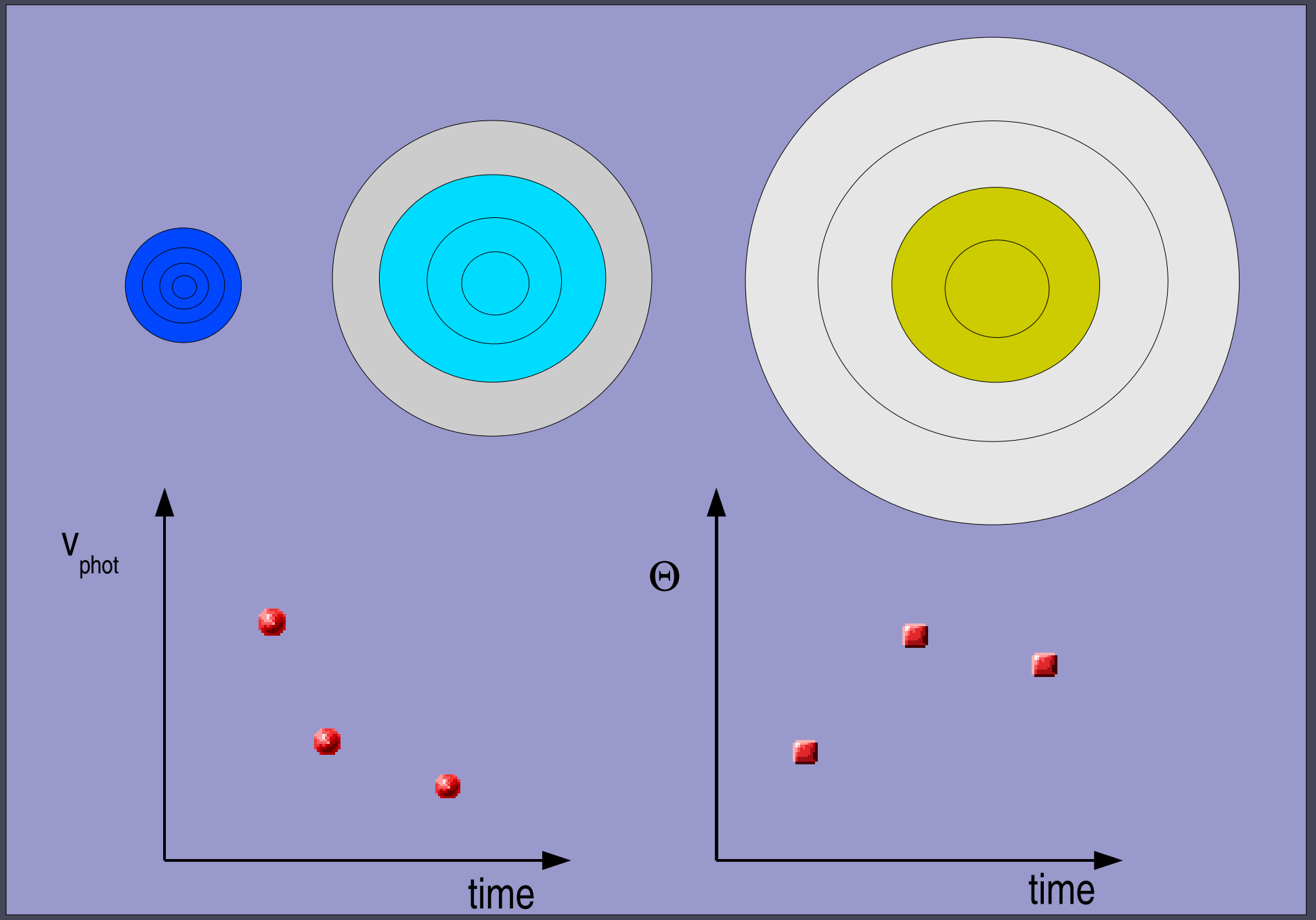
Obtaining the distance

if we know Θ and v_{phot} :

$$t = t_{ex} + D \cdot \frac{\Theta}{v_{phot}}$$ (Schmidt et al. 1994)

or: $$\frac{\Theta}{v_{phot}} = \frac{1}{D}(t - t_{ex})$$ (Dessart & Hillier, 2006)

2 unknowns: D, t_{ex} ==> at least 2 points are needed


V phot
time
Θ
time

Computing the angular radius

flux-based:

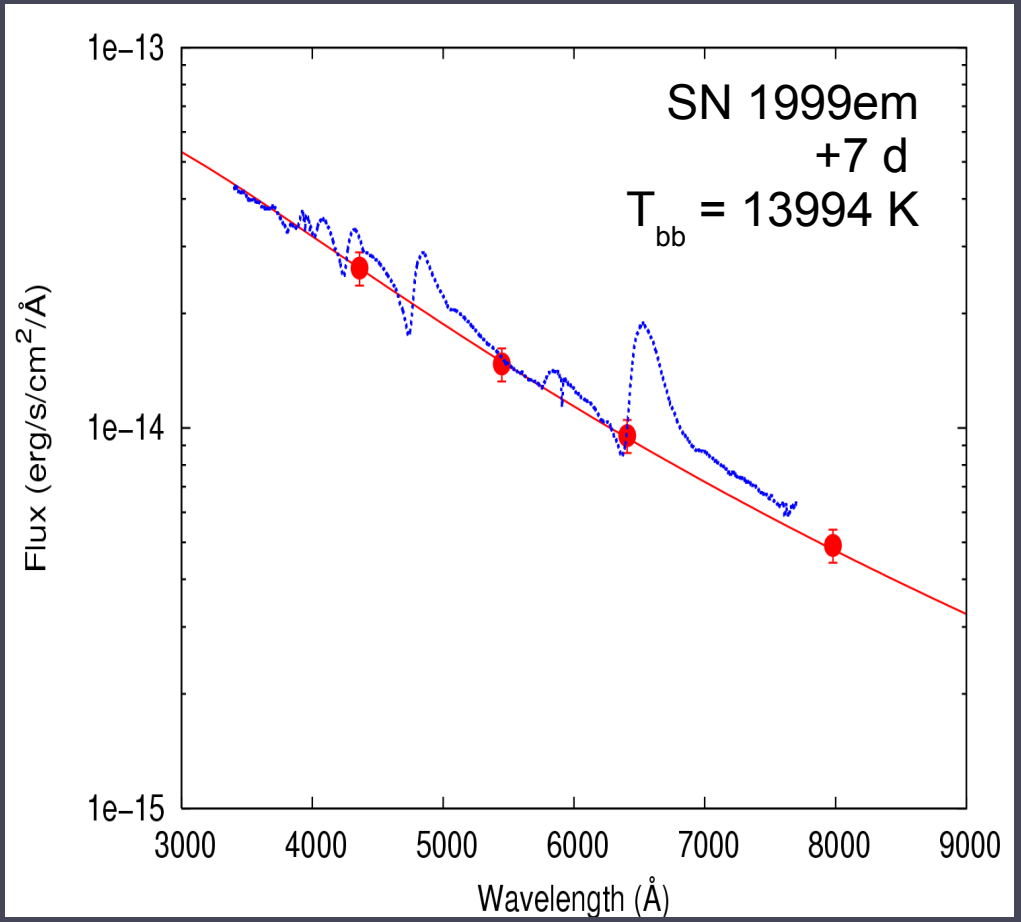
$$\Theta = \frac{1}{\zeta}\sqrt{\frac{f_\lambda}{\pi B_\lambda(T)}}$$

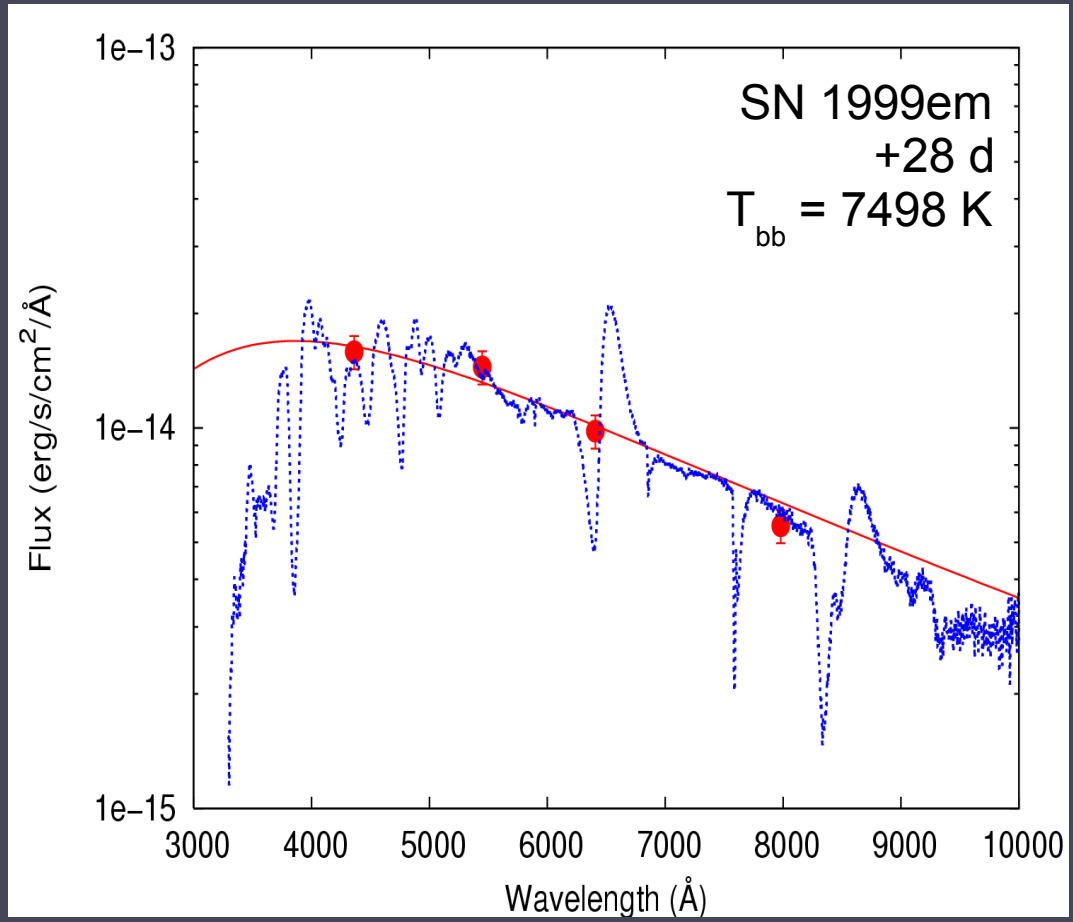
magnitude-based:

$$\sum_\lambda \left[m_\lambda - A_\lambda + 5\log\Theta + 5\log\zeta - b_\lambda(T) \right]^2 = min$$

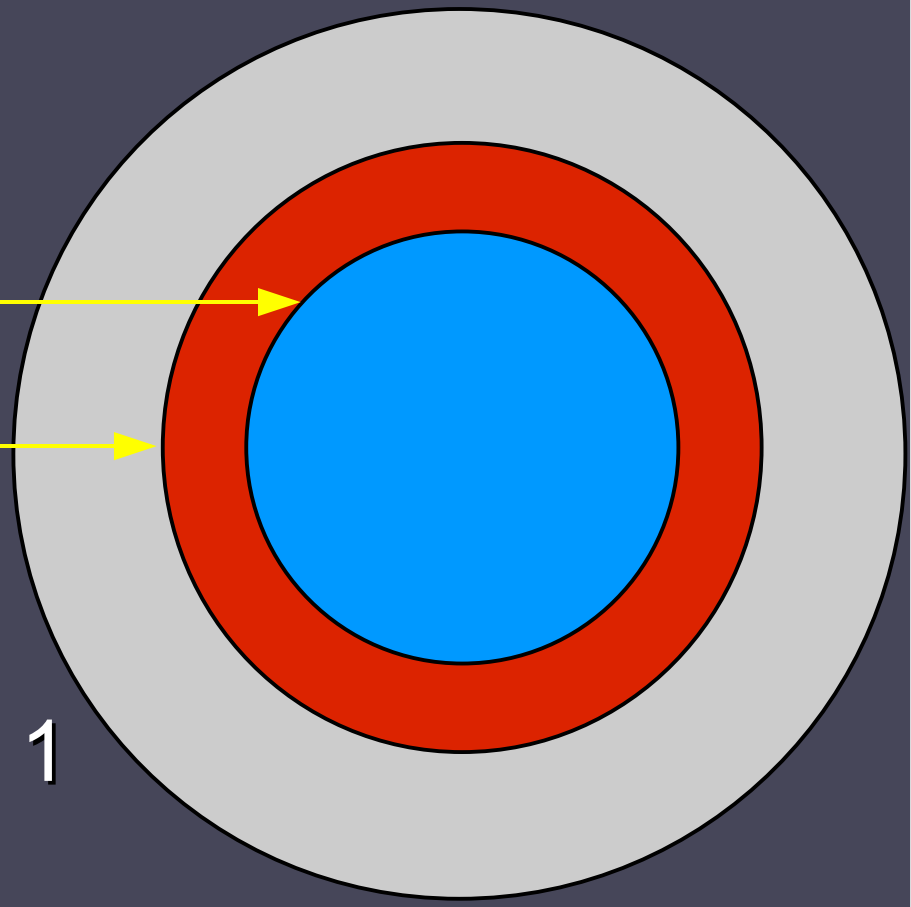
(Hamuy 2001; Leonard et al. 2002)

Measuring the color temperature Type II-P SNe





The correction (dilution) factors for Type II-P SNe

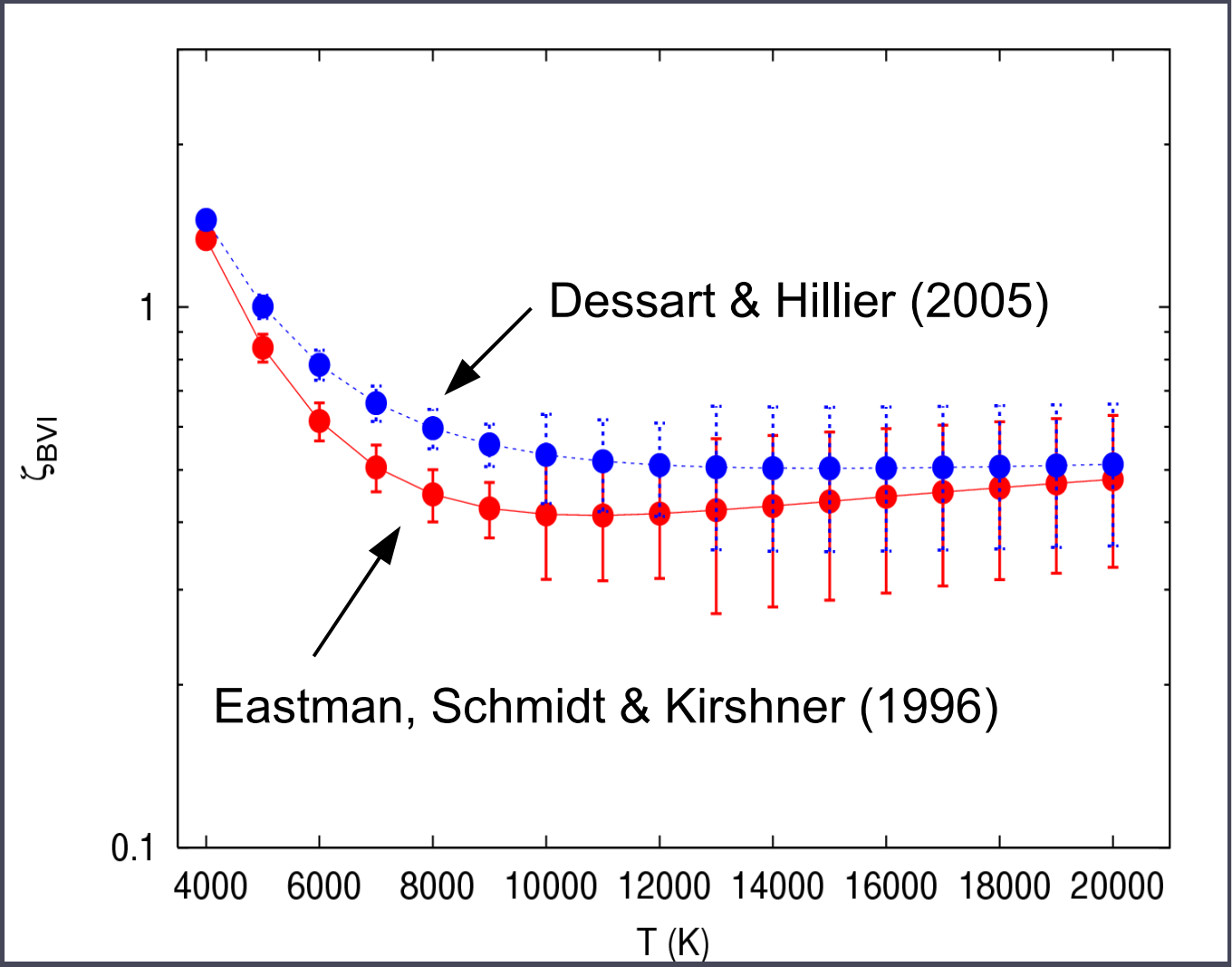


- origin of bb photons: thermalization depth (R_{th})
- photosphere: surface of last scattering ($R_{ph} > R_{th}$)
- $$F_\lambda \approx 2\sqrt{\frac{\kappa}{\sigma}}\cdot\left(\frac{R_{th}}{R_{ph}}\right)^2 B_\lambda(T)$$ => $\zeta^2 < 1$
- but: line absorption at low T also decreases the observed flux: $T_{color} < T_{true}$ => $\zeta^2 > 1$

The correction (dilution) factors for Type II-P SNe

Model phases:

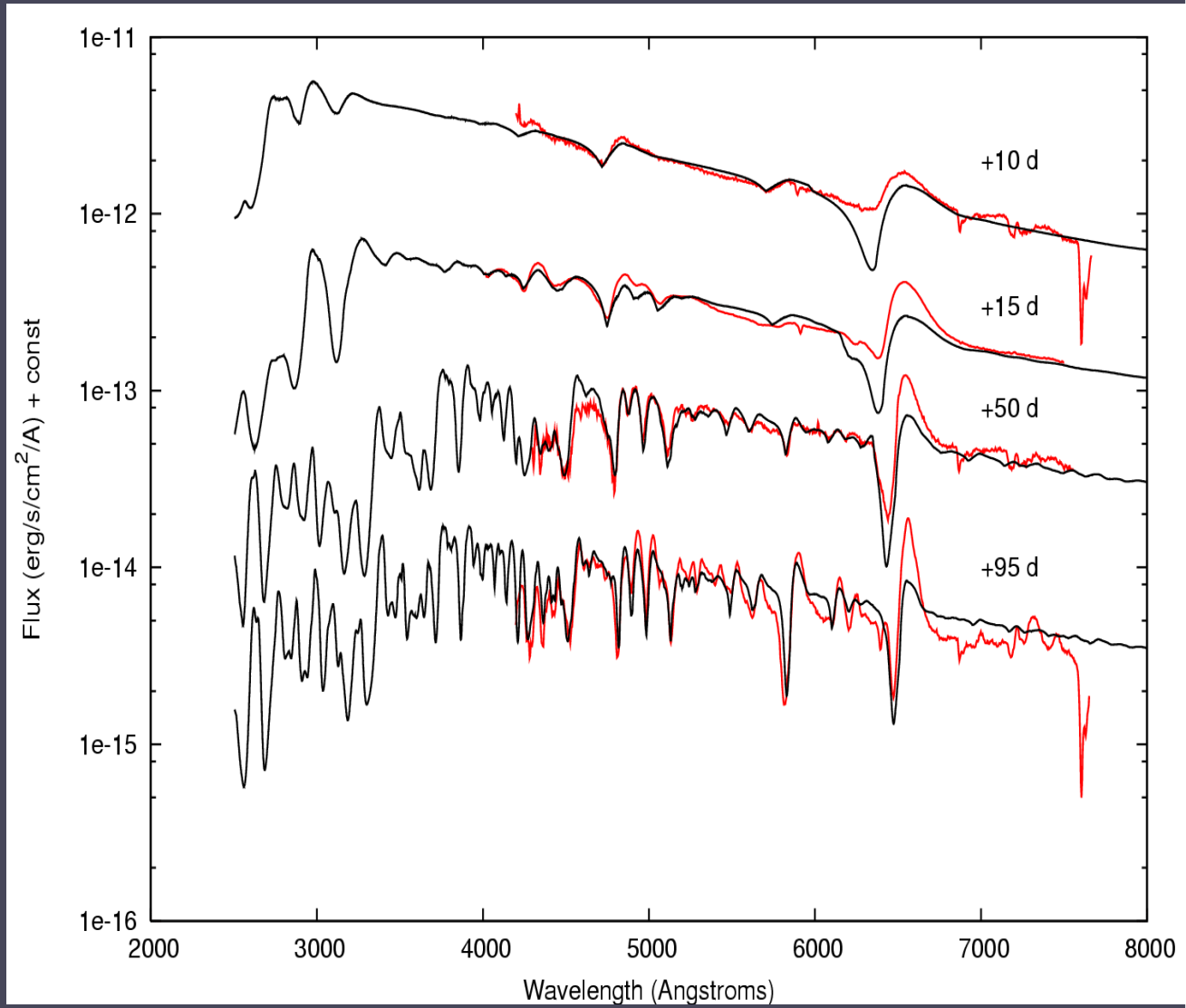
- 10 - 60 days
(Eastman et al. 1996)
- 5 - 40 days
(Dessart & Hillier 2005)



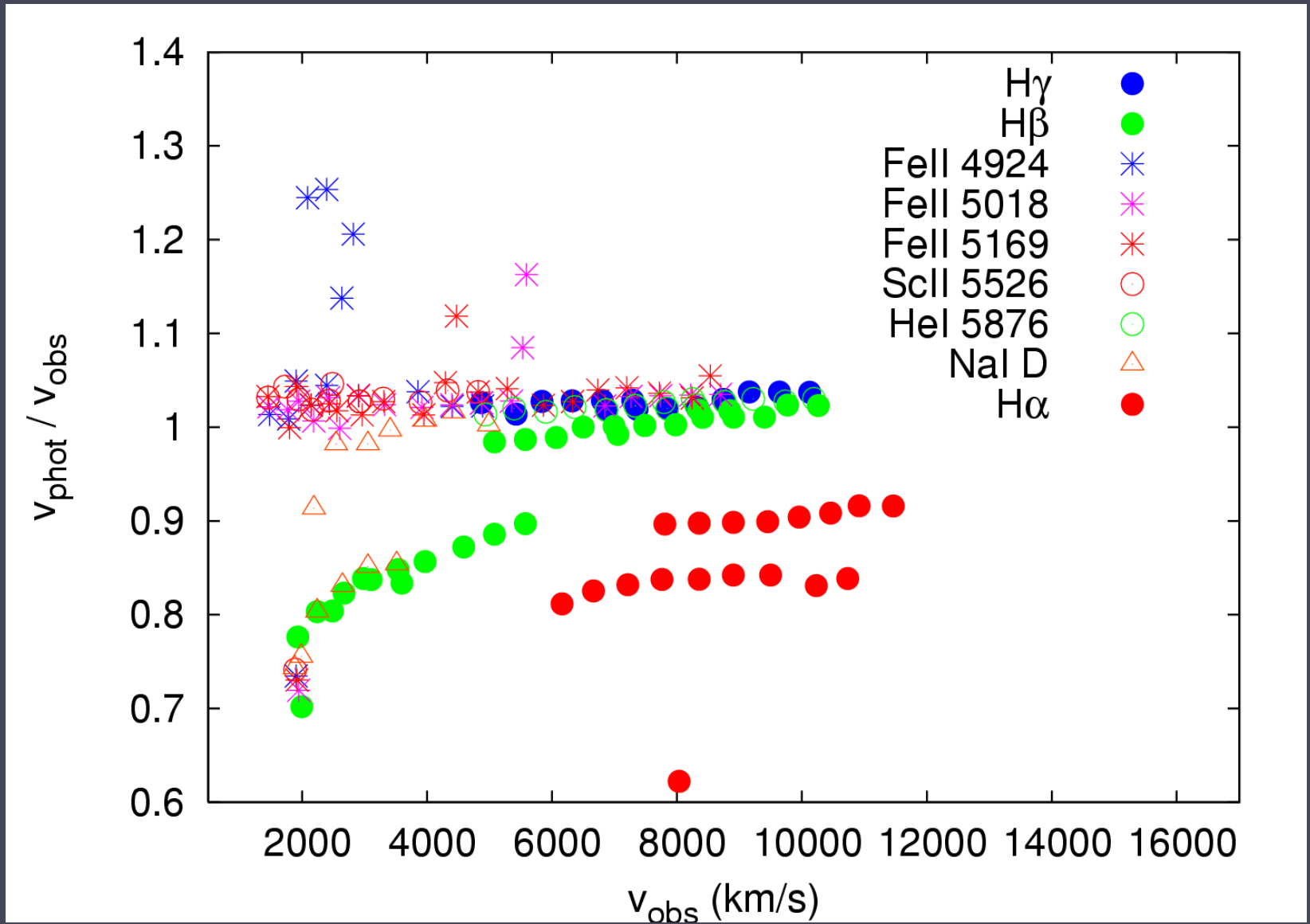
Measuring photospheric velocities for Type II-P SNe

SYNOW models for Type II-P SNe between 10 -- 95 days

for each phase: a model sequence with many v_{ph}

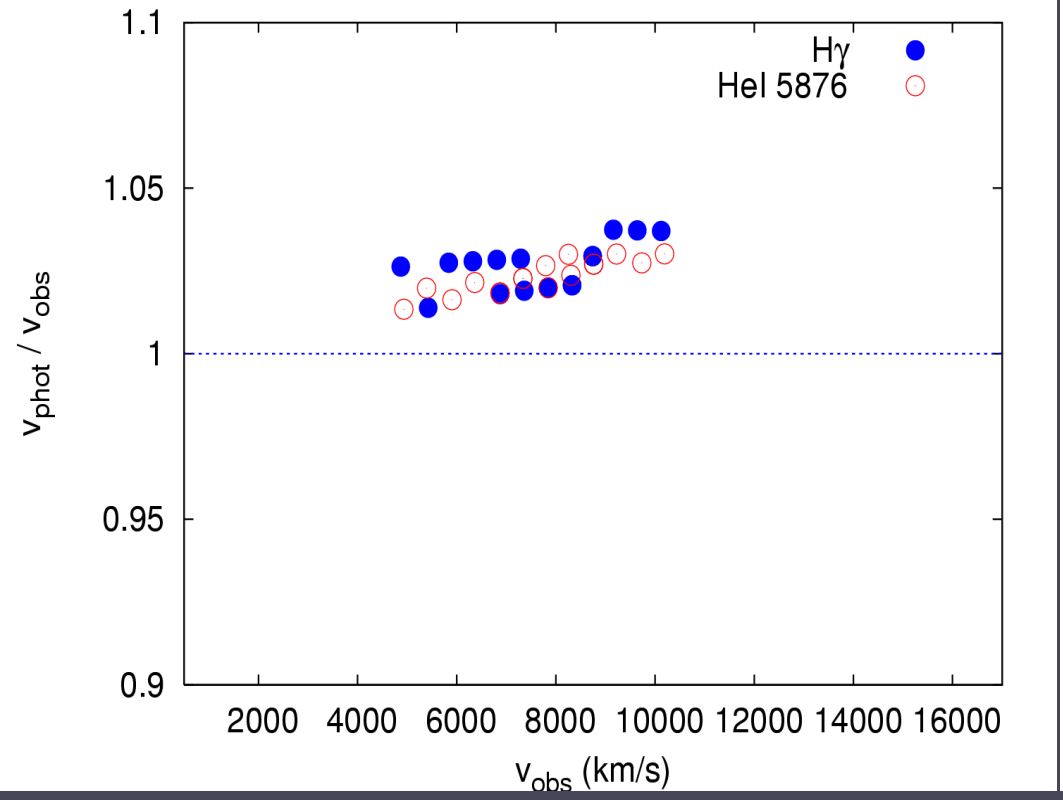


Measuring photospheric velocities for Type II-P SNe

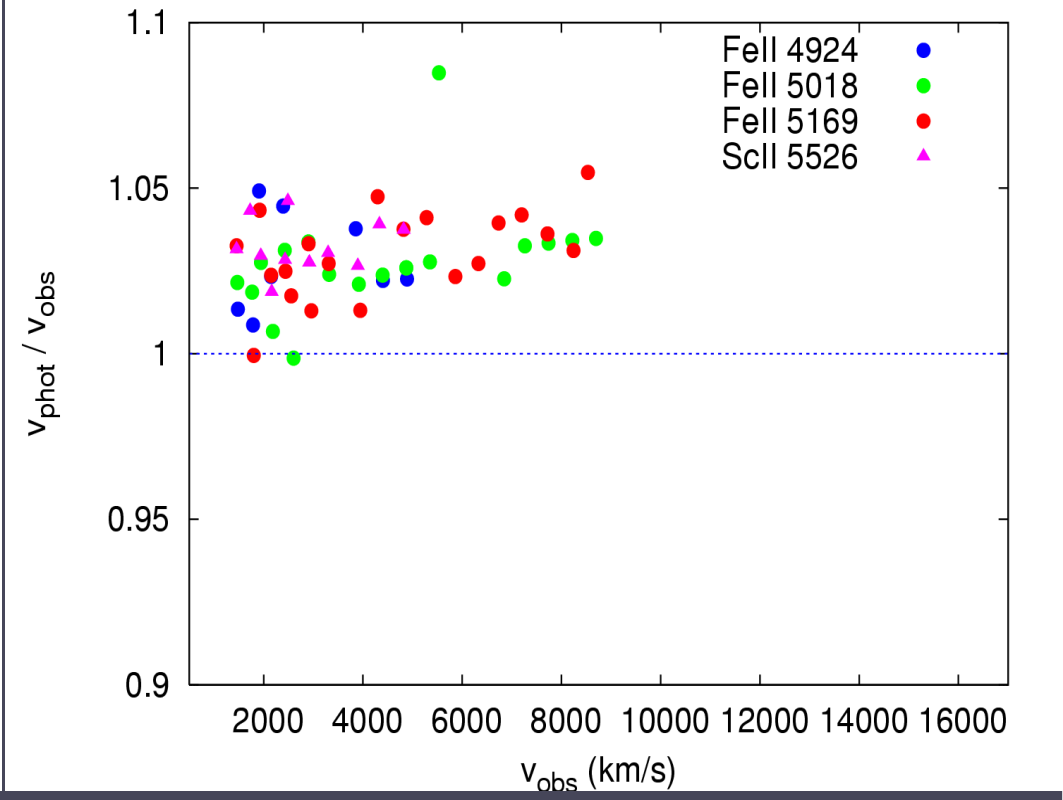


Measuring photospheric velocities for Type II-P SNe

Early phases



Late phases



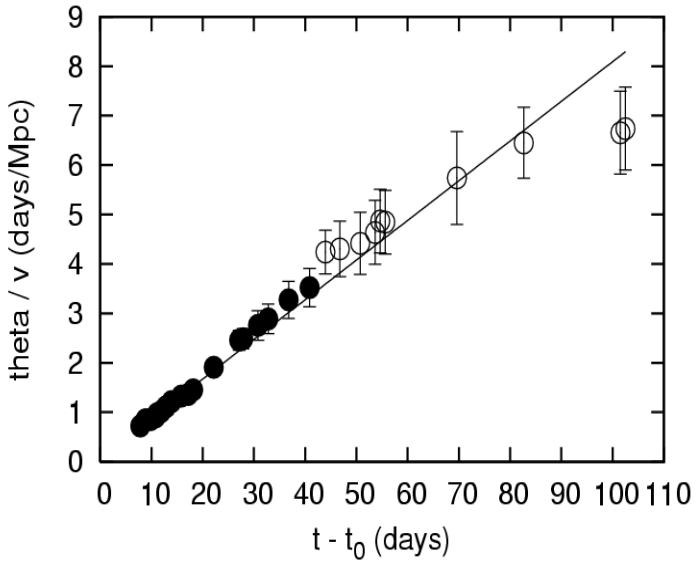
Examples: SN 1999em

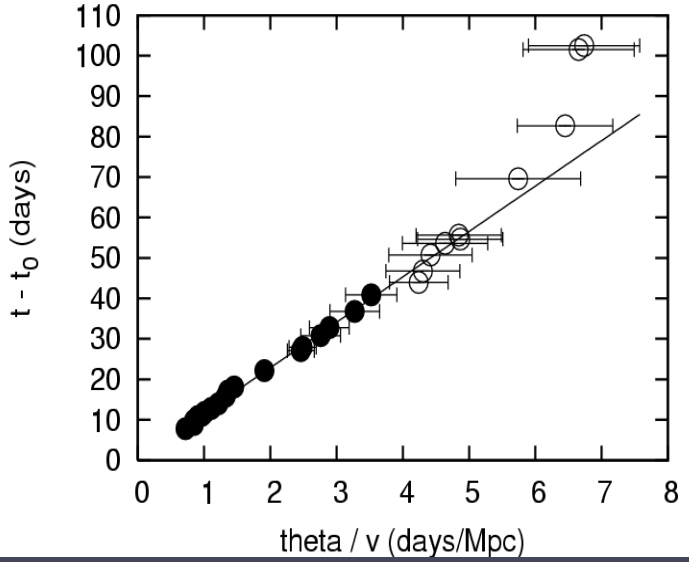
Using Dessart & Hillier correction factors between
t = 5 - 35 days:

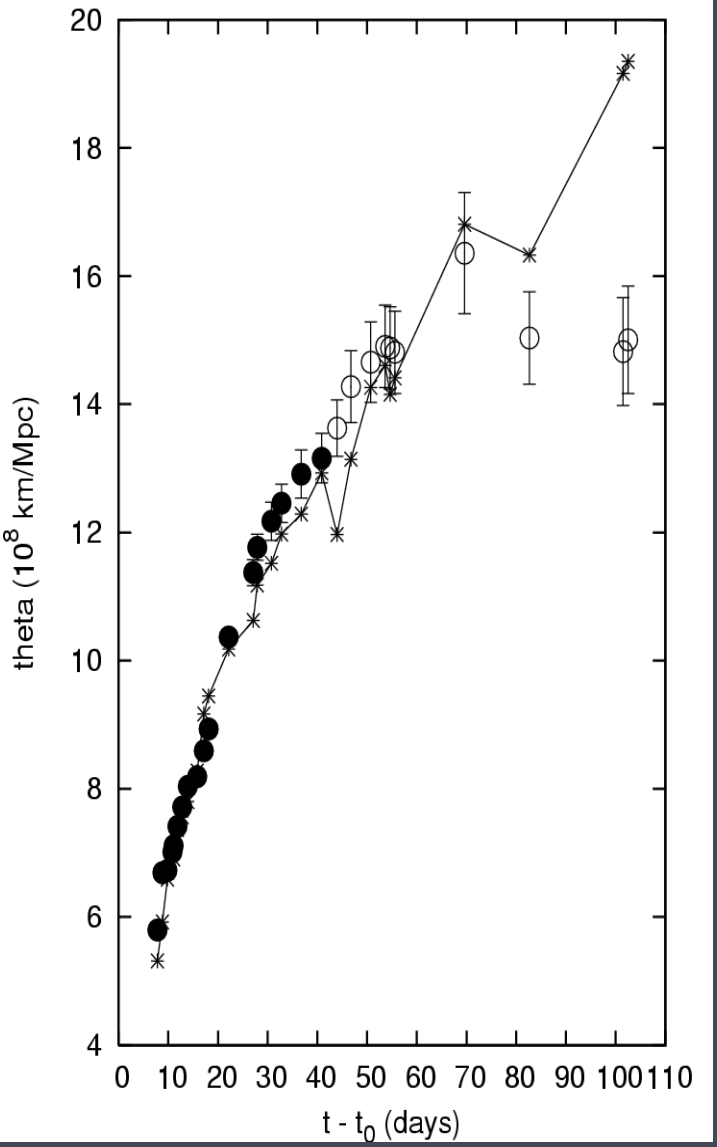
D_{EPM} = 11.8 ± 1 Mpc

D_{Cep} = 11.7± 1.0 Mpc
(Leonard et al. 2003)

D_{EPM} = 11.5 ± 1.0 Mpc
(Dessart & Hillier, 2006)





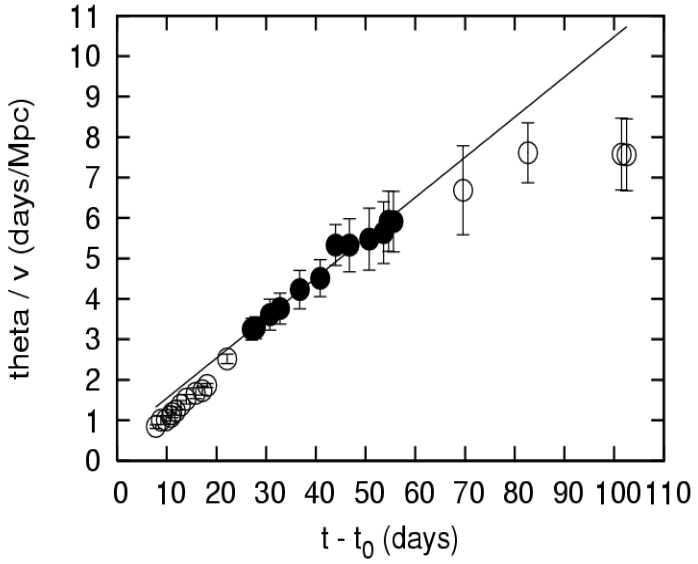


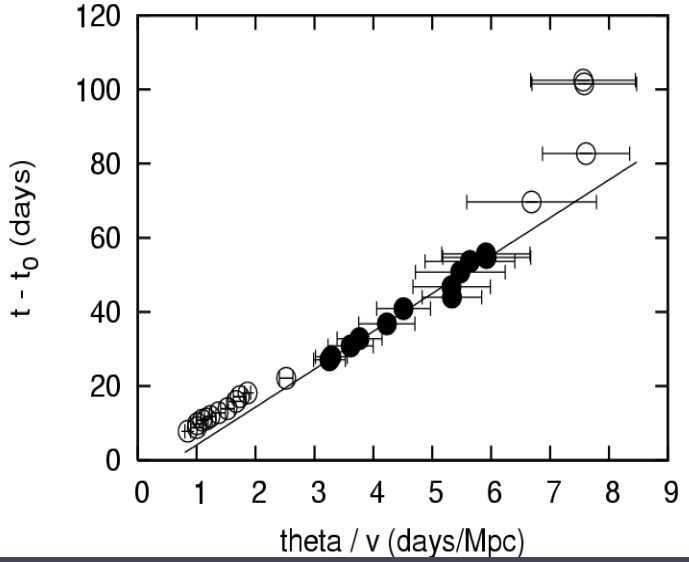
Examples: SN 1999em

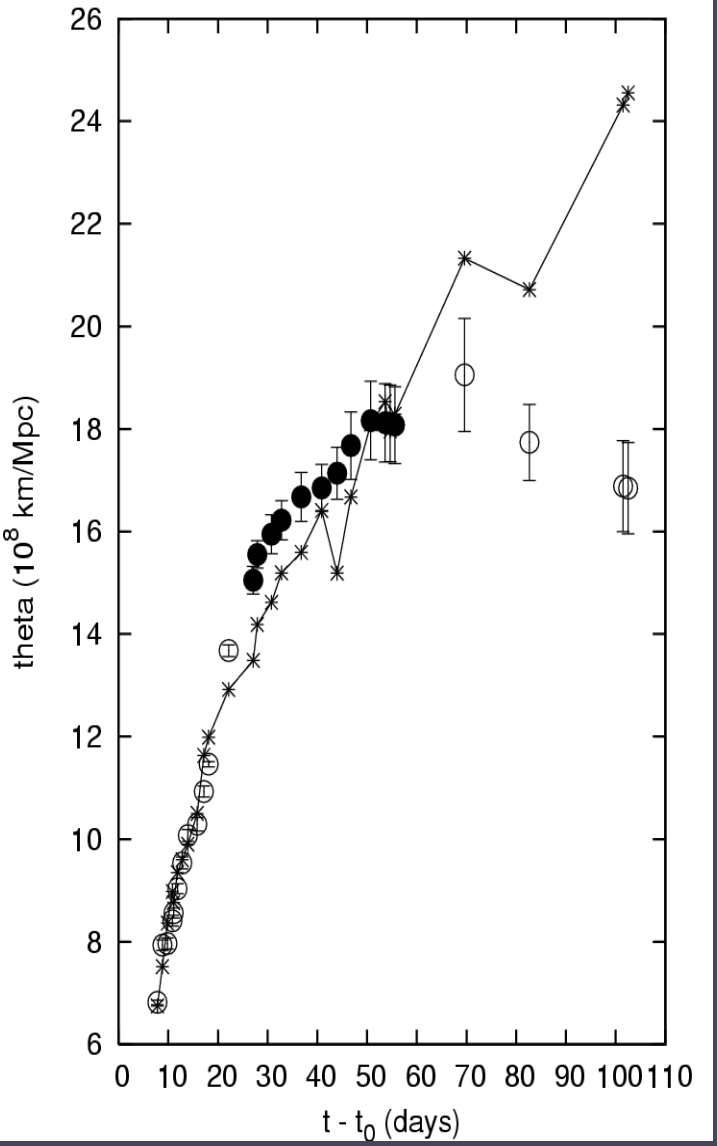
Using Eastman et al. correction factors between
t = 30 - 60 days:

D_{EPM} = 10.1 ± 1 Mpc

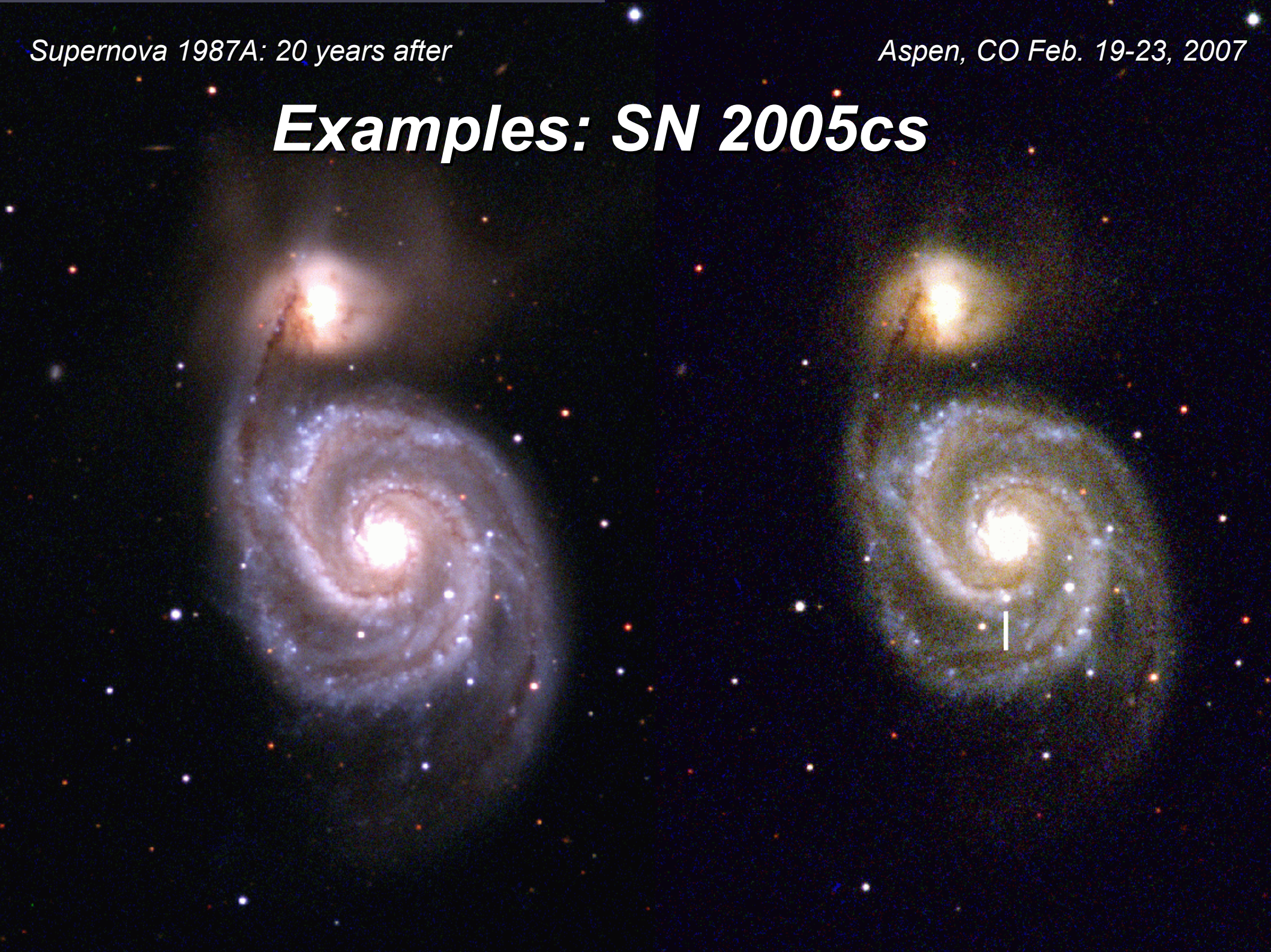
D_{Cep} = 11.7± 1.0 Mpc
(Leonard et al. 2003)







Examples: SN 2005cs

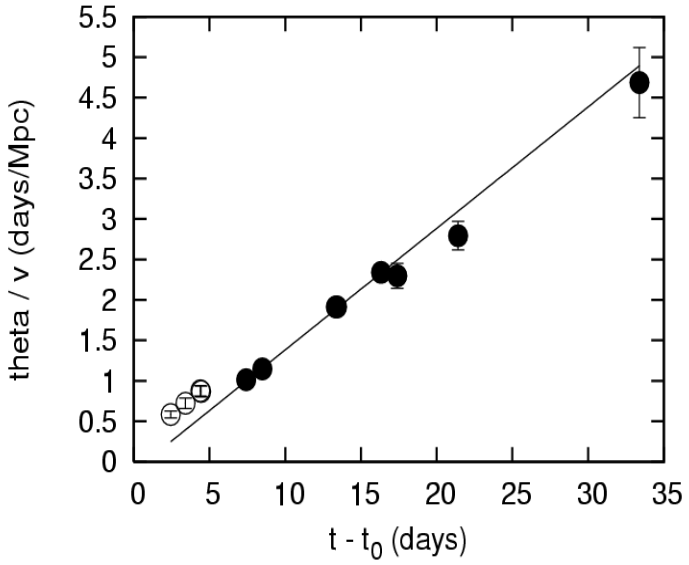


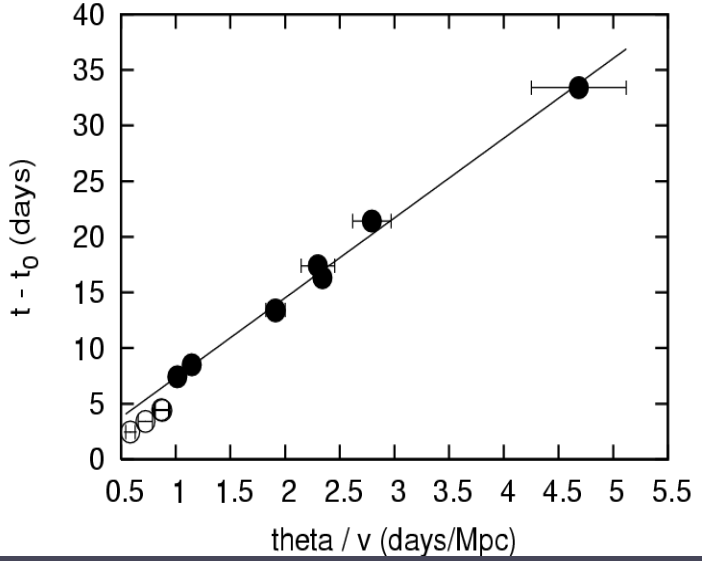
Examples: SN 2005cs

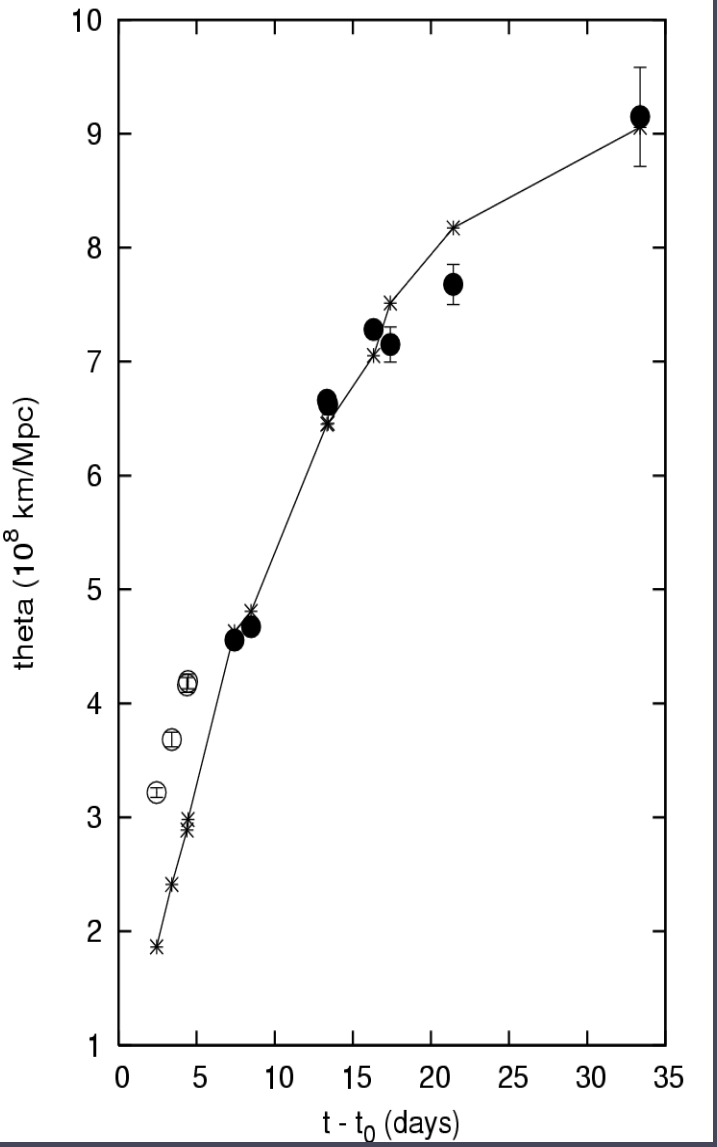
Using Dessart & Hillier correction factors between
t = 5 - 35 days:

D_{EPM} = 6.9 ± 1 Mpc

D_{ave} = 7.1± 1.2 Mpc
(Takats & Vinko 2006)

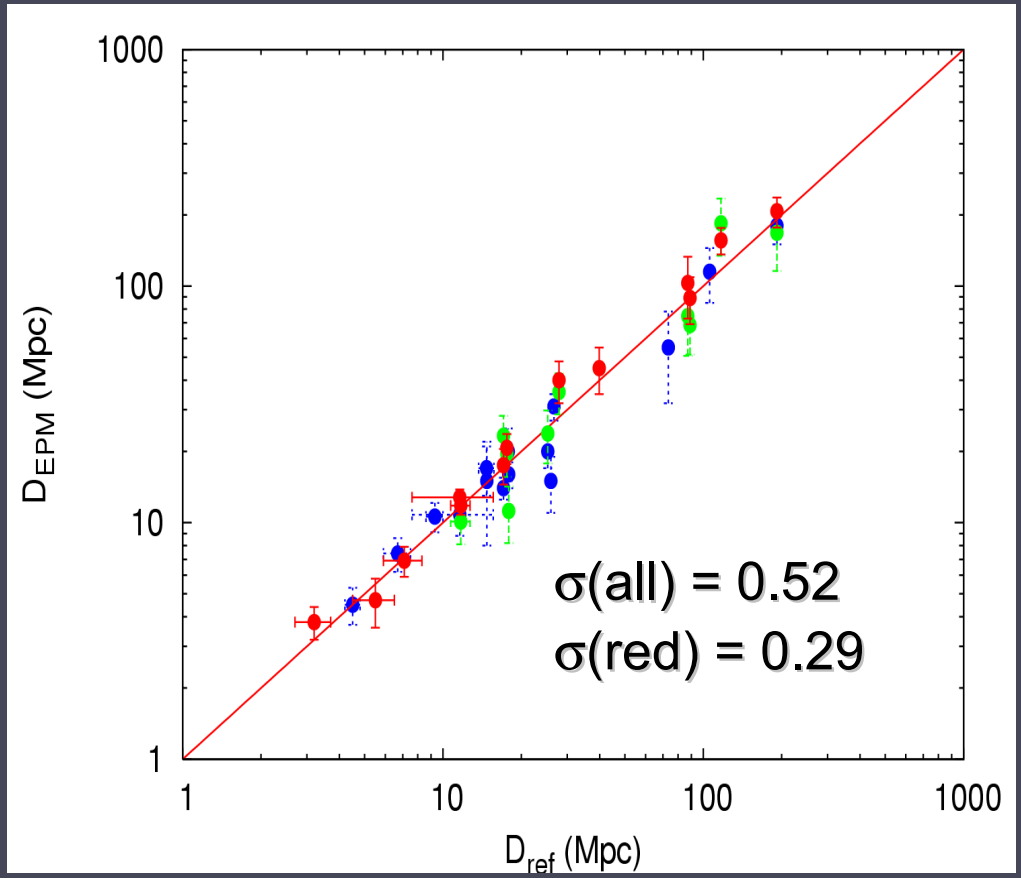




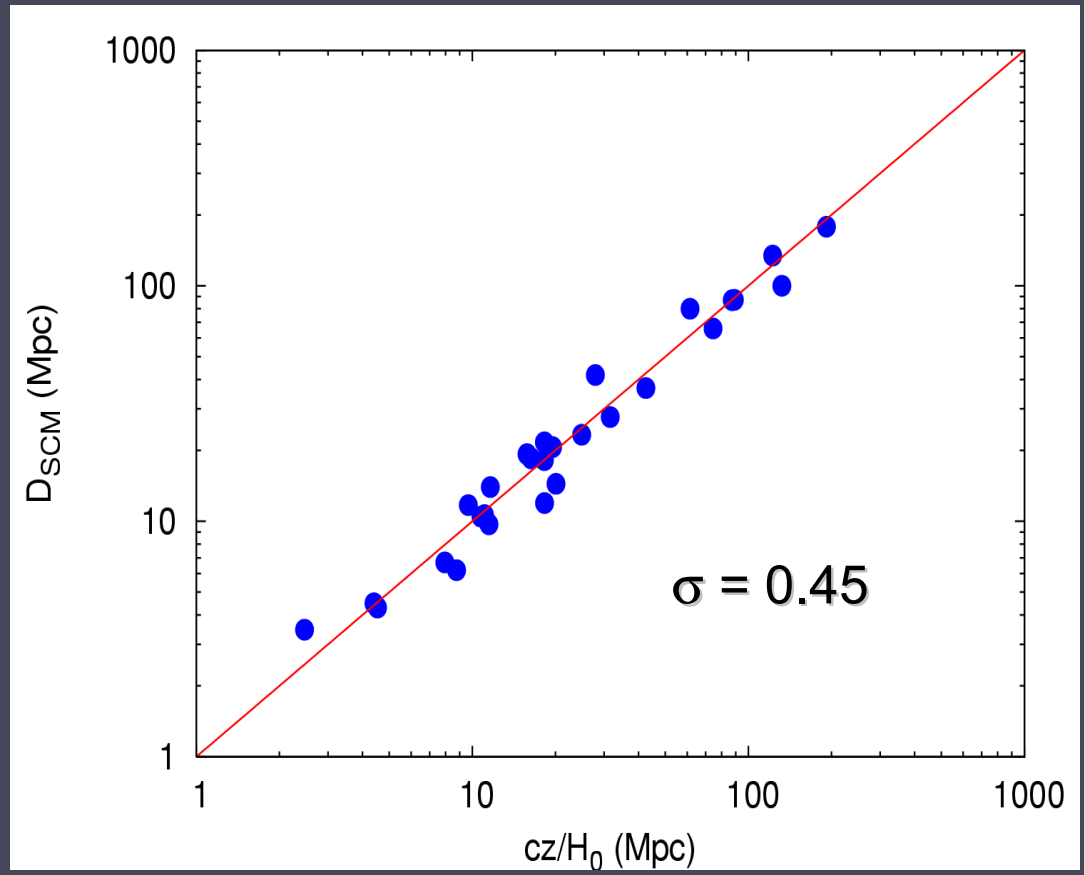


Comparison with other methods

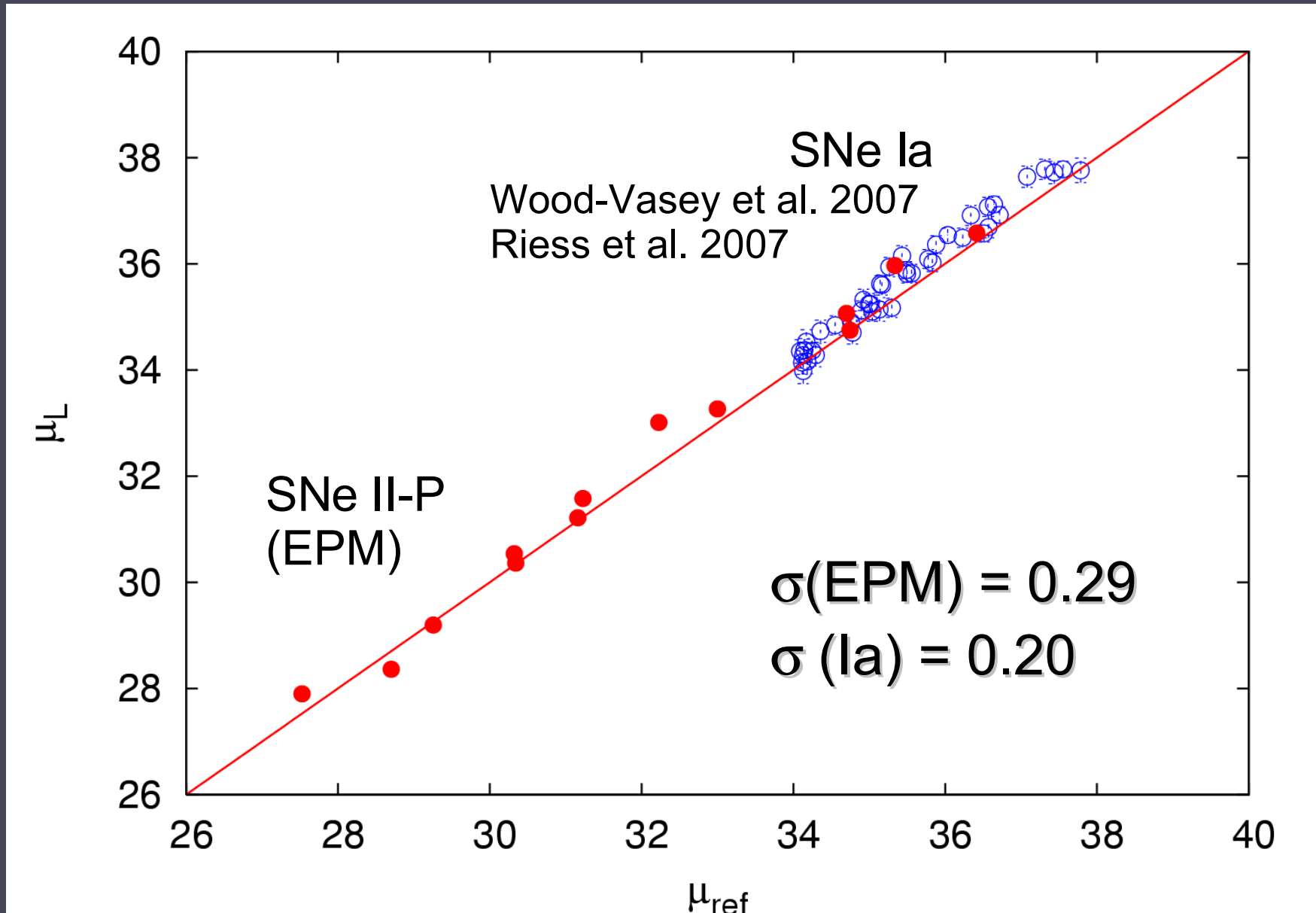
EPM



SCM (Hamuy, 2003)



Comparison with other methods



Conclusions

- EPM can give reliable distances to SNe II-P
- May serve as an independent method to test SNe Ia distances, even to high z

Thank you for your attention